

PRELIMINARY ANALYSIS OF HY-2 ACMR DATA

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ABSTRACT

Water vapor and cloud liquid water can influence the accuracy of sea surface height that spaceborne altimeter measures. Atmospheric correction microwave radiometer (ACMR) can be used to retrieve the amount of water vapor and cloud liquid water by measuring radiation from atmosphere and earth's surface. HY-2 satellite is a Chinese satellite for ocean dynamic environmental monitoring. ACMR is one payload of HY-2 satellite. Up to now, ACMR has been in operation for more than three years. In-orbit system stability of three years is assessed. The data of ACMR brightness temperature are matched to that of ECMWF wet tropospheric path delay in same space and time. The water vapor and cloud liquid water retrieval algorithm is derived. The wet tropospheric path delay deviations are less than 1.5cm. Brightness temperatures and path delay of ACMR were compared with that of AMR. The average and standard deviations of wet tropospheric path delay are 1.27mm and 0.68mm.

Index Terms— HY-2 Satellite, ACMR, Path Delay, Cross-calibration

1. INTRODUCTION

HY-2 satellite is a Chinese satellite for ocean dynamic environmental monitoring. It was launched on Aug.16, 2011. ACMR on board of HY-2 is a nadir viewing three-band microwave radiometer which measures radiation from atmosphere and earth's surface at frequencies of 18.7GHz, 23.8GHz and 37GHz. It is used to retrieve the amount of water vapor and cloud liquid water so as to correct the path delay that altimeter's signals travel from satellite to the ocean surface and back.

ACMR is a full power microwave radiometer. System calibration uses matched loads and cold space background. Unlike other spaceborne path delay correction microwave radiometer, ACMR measurement antenna is a deployable offset parabolic antenna with three feeds. The reflector is fixed on the base before launch. When ACMR is in orbit, the reflector is spread by hinges and the three beams distribute in the nadir direction within 2.5 degree along the satellite flight direction. The measurement antenna

beamwidth at different frequency is 1.4°, 1.1° and 0.6°, respectively.

2. SYSTEM STABILITY ASSESSMENT

ACMR has been working from Sep.1, 2011. In order to assess in-orbit performance, the system sensitivity should be calculated at different time firstly. Because of the fluctuation of target radiation, some cold space and hot source data was randomly selected to calculate in-orbit system sensitivity about every six months. The results demonstrate that the in-orbit system sensitivity is less than 0.25K.

In order to further monitor ACMR system stability, the system gain fluctuation is assessed for more than three years. The microwave receiver temperature influences system gain. When ACMR is in orbit, microwave receiver temperature of each channel changes with time. The temperature of microwave receivers shows a periodical variation. ACMR measurement data of hot source and cold space at certain temperature was analyzed so as to further eliminate the impact of receiver temperature variation. The temperature should be that the receiver experienced the most times from beginning to now. The selected temperature is 293K. The data between 292.9 and 293.1 are found out to calculate system gain. Table 1 to table 3 show each channel gain at 293K. The gain is defined as V/T .

Table 1 18.7GHz channel gain at 293K

	Gmean	Gstd	Gmax-Gmin	Gmax-Gmin/Gmean
All the data(Ts=293)	0.01641	0.000044	0.000250	0.015
1	0.01629	0.000012	0.000085	0.005
2	0.01634	0.000010	0.000067	0.004
3	0.01633	0.000009	0.000060	0.004
4	0.01635	0.000010	0.000076	0.005
5	0.01636	0.000009	0.000076	0.005
6	0.01638	0.000010	0.000058	0.004
7	0.01640	0.000009	0.000071	0.004
8	0.01638	0.000009	0.000065	0.004
9	0.01642	0.000009	0.000053	0.003
10	0.01644	0.000010	0.000076	0.005
11	0.01643	0.000010	0.000073	0.004
12	0.01645	0.000010	0.000084	0.005
13	0.01644	0.000010	0.000073	0.004
14	0.01645	0.000010	0.000073	0.004
15	0.01643	0.000011	0.000079	0.005
16	0.01641	0.000010	0.000054	0.003
17	0.01644	0.000010	0.000091	0.006
18	0.01647	0.000010	0.000047	0.003

Table 2 23.8GHz channel gain at 293K

	Gmean	Gstd	Gmax-Gmin	Gmax-Gmin/Gmean
All the data(Ts=293)	0.01663	0.000035	0.000220	0.013
1	0.01661	0.000011	0.000087	0.005
2	0.01666	0.000011	0.000075	0.005
3	0.01668	0.000011	0.000077	0.005
4	0.01668	0.000011	0.000082	0.005
5	0.01666	0.000011	0.000085	0.005
6	0.01666	0.000011	0.000071	0.004
7	0.01666	0.000012	0.000092	0.006
8	0.01665	0.000011	0.000091	0.005
9	0.01666	0.000011	0.000061	0.004
10	0.01667	0.000011	0.000092	0.006
11	0.01665	0.000012	0.000080	0.005
12	0.01664	0.000011	0.000081	0.005
13	0.01662	0.000011	0.000082	0.005
14	0.01661	0.000011	0.000089	0.005
15	0.01658	0.000012	0.000086	0.005
16	0.01652	0.000010	0.000054	0.003
17	0.01656	0.000012	0.000099	0.006
18	0.01657	0.000011	0.000064	0.004

Table 3 37GHz channel gain at 293K

	Gmean	Gstd	Gmax-Gmin	Gmax-Gmin/Gmean
All the data(Ts=293)	0.01453	0.000045	0.000265	0.018
1	0.01461	0.000013	0.000103	0.007
2	0.01457	0.000012	0.000088	0.006
3	0.01459	0.000012	0.000080	0.005
4	0.01458	0.000015	0.000094	0.006
5	0.01457	0.000012	0.000087	0.006
6	0.01457	0.000012	0.000092	0.006
7	0.01455	0.000012	0.000086	0.006
8	0.01457	0.000012	0.000092	0.006
9	0.01451	0.000012	0.000103	0.007
10	0.01450	0.000012	0.000103	0.007
11	0.01447	0.000012	0.000085	0.006
12	0.01448	0.000011	0.000100	0.007
13	0.01450	0.000013	0.000074	0.005
14	0.01448	0.000012	0.000075	0.005
15	0.01447	0.000012	0.000080	0.006
16	0.01443	0.000011	0.000075	0.005

The variation of microwave receiver gain of each channel is very small.

3. PATH DELAY RETRIEVAL ALGORITHM

ACMR on board of HY-2 has been working for more than three years. The data of ACMR brightness temperature are matched to that of ECMWF wet tropospheric path delay in 2012. The latitude range of data is between 60°S and 60°N. The time and space window are 30 minutes and 0.25° in latitude and longitude, respectively. ECMWF wet tropospheric path delay data as reference are bilinear interpolated in time and space. All land data and the data within 50 km off land were removed from the matched dataset. One half of the matched data is randomly selected and used to derive retrieval algorithm. The other half is used to validate the algorithm.

The algorithm formula is shown as the following equation :

$$PD_v = a_0 + a_1 \cdot \ln(280-Tv19) + a_2 \cdot \ln(280-Tv23) + a_3 \cdot \ln(280-Tv37)$$

Where

$$a_0=0.2578, a_1=-0.6519, a_2=0.8584, a_3=-0.2609.$$

Figure 1 shows the wet tropospheric path delay of HY-2 ACMR versus ECMWF. In figure 1, the first half brightness temperature matched data are used to derive retrieval algorithm with ECMWF path delay data. The atmospheric wet path delay of HY-2 is calculated by the algorithm formula. Figure 2 shows histogram of wet tropospheric path delay deviation between HY-2 ACMR and ECMWF. The data are used to validate the algorithm. The wet tropospheric path delay deviations of algorithm and validation are 1.46cm and 1.47cm, respectively.

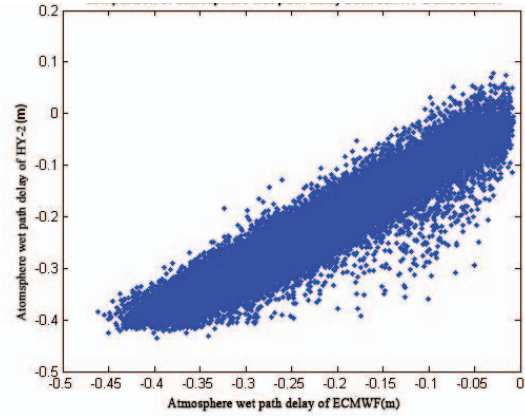


Fig.1 wet tropospheric path delay of HY-2 ACMR vs ECMWF

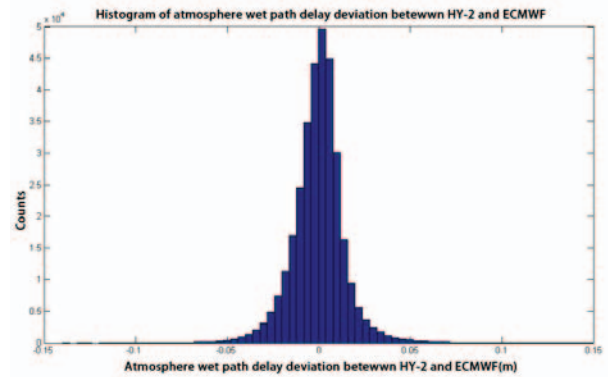


Fig.2 histogram of wet tropospheric path delay deviation between HY-2 ACMR and ECMWF

4. CROSS-CALIBRATION WITH AMR

AMR on board of Jason-2 operates at 18.7GHz, 23.8GHz and 34 GHz with nadir viewing of wet tropospheric path delay for correcting the altimeter on the same satellite. The frequency channel of ACMR is similar to that of AMR.

Cross-calibration was done by comparing brightness temperatures of ACMR with that of AMR from Oct.14, 2011 to Oct.30, 2013. The interval of space is 0.5° in latitude and longitude. The interval of time is 30 minutes. Some data were removed from the matched database:

- (1) Data whose central pixels between the AMR and the 37 GHz channel of ACMR were more than 0.1° apart;
- (2) All land data;
- (3) All cloud data with a liquid water content greater than 0 in the Jason-2 data product;
- (4) Data within 50 km off land;
- (5) Data with a brightness temperature greater than 160 K at 18.7 GHz and 175 K in the Ka bands when considering rain in the pixels;
- (6) Data with the latitude greater than 60 considering the path delay algorithm.

In total, 8821 pixels of ACMR were matched with that of AMR. Wet tropospheric path delay of ACMR was calculated with the brightness temperature data matched with that of AMR by the algorithm formula derived in the last chapter. Figure 3 to figure 5 show brightness temperatures of ACMR versus AMR at different channels. Figure 6 shows wet tropospheric path delay of ACMR versus AMR.

Brightness temperatures of AMR are very similar to that of ACMR. The biases are 0.39K, 0.26K, and -3.67 K at 18.7GHz, 23.8GHz and Ka band, respectively. The standard deviations are 1.21K, 1.93K and 1.56K. In AMR, the Ka band frequency is 34GHz. In ACMR, the Ka band frequency is 37GHz. That is why the bias of brightness temperatures is much more in Ka band channel. The average deviation of wet tropospheric path delay is 1.27cm. The standard deviation is 0.68cm. Usually, the average deviation can be corrected as a constant. The difference of wet tropospheric path delay retrieved by ACMR and AMR is small.

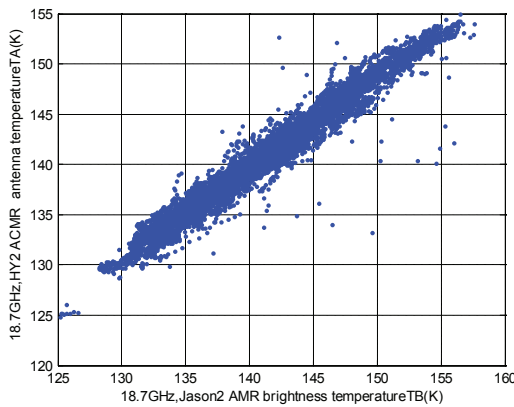


Fig.3 brightness temperatures of ACMR vs AMR at 18.7GHz

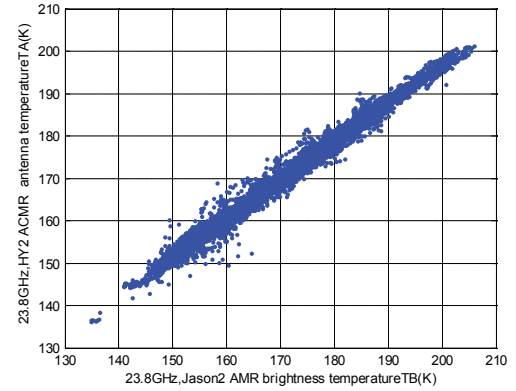


Fig.4 brightness temperatures of ACMR vs AMR at 23.8GHz

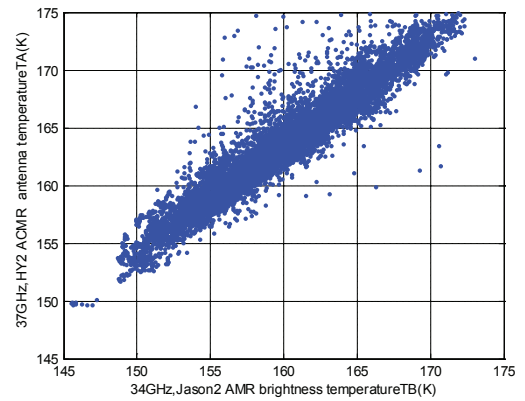


Fig.5 brightness temperatures of ACMR vs AMR at Ka band

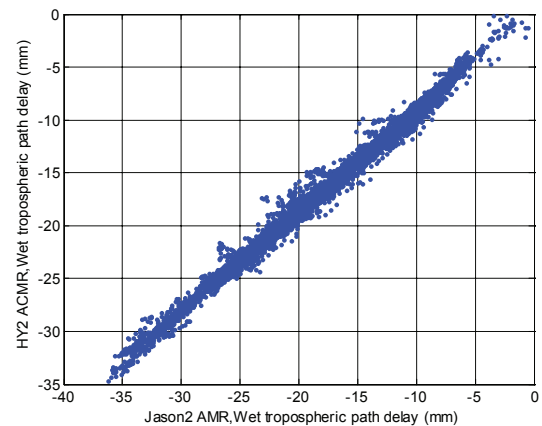


Fig.6 wet tropospheric path delay of ACMR vs AMR

5. CONCLUSION

ACMR on board of HY-2 has been working for more than three years. The data of ACMR brightness temperature are matched to that of ECMWF wet tropospheric path delay in same space and time. The path delay retrieval algorithm is derived and validated. The wet tropospheric path delay deviations of algorithm and validation are 1.46cm and 1.47cm, respectively. Cross-calibration was done by comparing brightness temperatures and path delay of ACMR with that of AMR. The standard deviations are 1.21K, 1.93K and 1.56K at 18.7GHz, 23.8GHz and Ka band, respectively. The average and standard deviations of wet tropospheric path delay are 1.27mm and 0.68mm.